Bolig 2020 med godt indeklima og høj brugerkomfort – Målerapport 3

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by

Evangelia Loukou
Per Kvols Heiselberg
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1. Introduction

The purpose of this report is to register the operation and performance of the project building Bolig 2020 for the period of 3 months from May to July. The building is located in Kildebjerg Søvej 32, Ry.

The aim is the long-term assessment of the indoor environmental quality and energy use of the dwelling. Additionally, the data is examined in order to verify that the systems' and equipment's performance matches their intended operation. The activation of natural ventilation and external shading devices will not be addressed in this report, due to the lack of registered data.

The evaluation of the performance of Bolig 2020 case study is based on a combination of standards and measured data.

The data registration is taking place every 5 minutes, approximately, in all rooms of the dwelling. The registered parameters are the following:

Parameters	**Comments**
Cold water consumption [m^3]	Total amount of water consumption for cold and hot water
Hot water consumption [m^3]	
Energy consumption:	
District heating [MWh]	
Floor heating pump [kWh]	
Nilan system [kWh]	Energy consumption for ventilation and production of sanitary hot water
Control system [kWh]	
Kitchen stove [kWh]	Energy consumption for the operation of 2 ovens and the cooking plate
Refrigerator [kWh]	Energy consumption for the refrigerator, wine cooler and exhaust hood
Quooker [kWh]	
Dish washer [kWh]	
Dryer [kWh]	
Washing machine [kWh]	
Other consumption [kWh]	Includes everything else

Temperature [°C], CO_2 level [ppm], Relative humidity level [%] and Damper opening [min/ max]:
Room 1
Room 2
Room 3
Master Bedroom
Living Room
Kitchen/ Dining Room

Temperature [°C], Relative humidity level [%] and Damper opening [min/ max]:
Utility Room
Bathroom 1

Bathroom 2

Temperature [°C] and Damper opening [min/ max]:
Wardrobe closet

For the compact unit:
Outdoor air temperature [°C]
Return air temperature [°C] and relative humidity [%]
Hot water temperature [°C]
Supply air temperature [°C]
Heat pump temperature [°C]
Ventilation speed [steps]

This report includes the registered period between the beginnings of May to the end of July. The data is presented both on a monthly level and for the entire period of the 3 months. The indoor environment evaluation is realized on a room basis, while the examined rooms are the most used ones, master bedroom, living room, kitchen and bathroom.

Each chapter addresses one of the examined parameters, including graphs for each examined month, as well as for the entire period (May, June and July). In the Annex are included more relevant graphs which are not in the report.

On the 26th of June there were no data registered, so there are missing information for that day. The percentage of time in each category has been calculated ignoring that specific day. The graphs presented in the Annex are also missing the values for that day, so the registered data from the previous day (25th of June) is connected with a straight line with that of the following day (27th of June).

From the 10th to the 24th of July, the dwelling is not occupied, while the residents are on summer holiday.

2. Energy Consumption

2.1 Energy consumption for ventilation and DHW

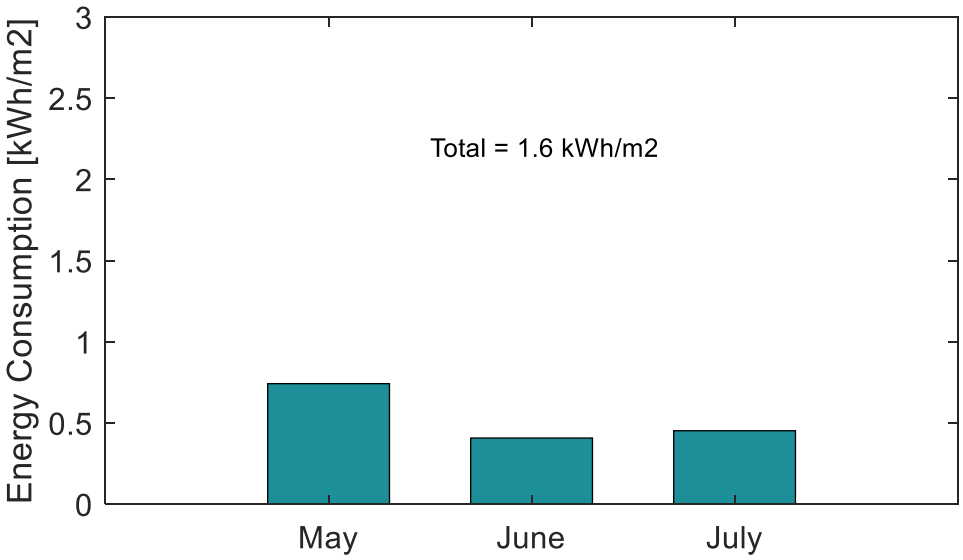

Figure 1: Energy consumption for ventilation and domestic hot water [kWh/m^2]

The sanitary hot water is produced by the compact ventilation system through the recovered energy from the exhaust air. If the demand is particularly large, an electrical backup supplements the production of hot water.

2.2 Energy consumption for heating

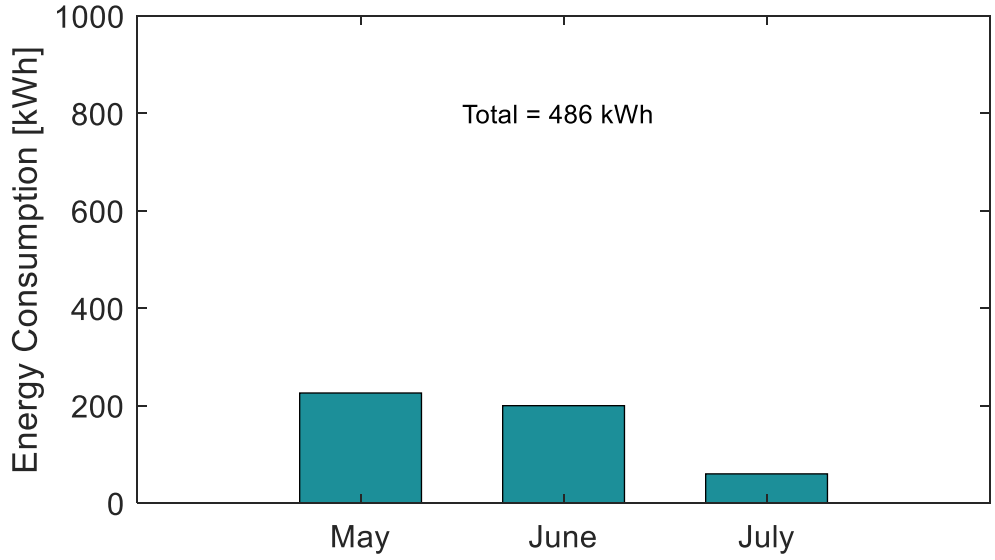

Figure 2: Energy consumption for heating [kWh]

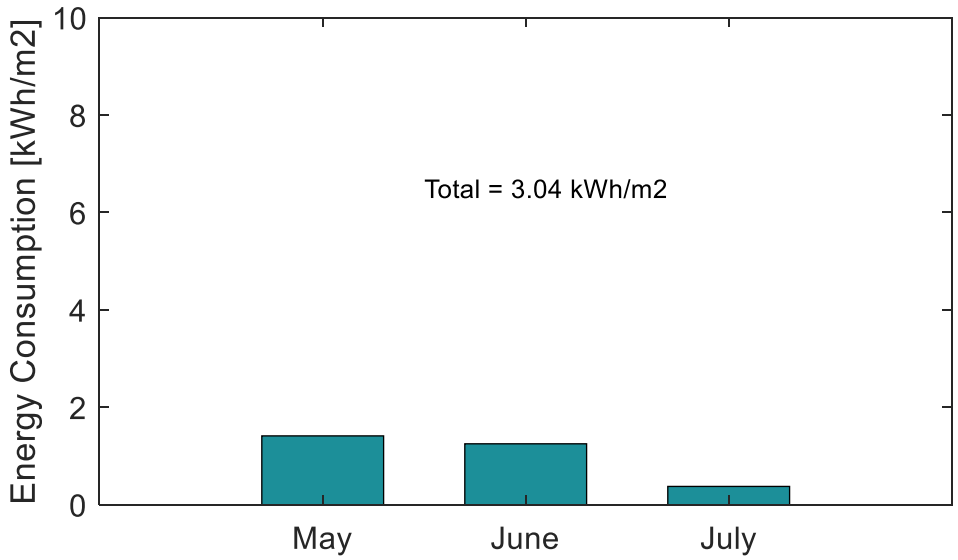

Figure 3: Energy consumption for heating [kWh/m^2]

Figures 2 and 3 illustrate the energy consumption for heating, given in [kWh] and [kWh/m^2], respectively. The values are taken from the data registered for "District Heating".

2.3 Electricity consumption

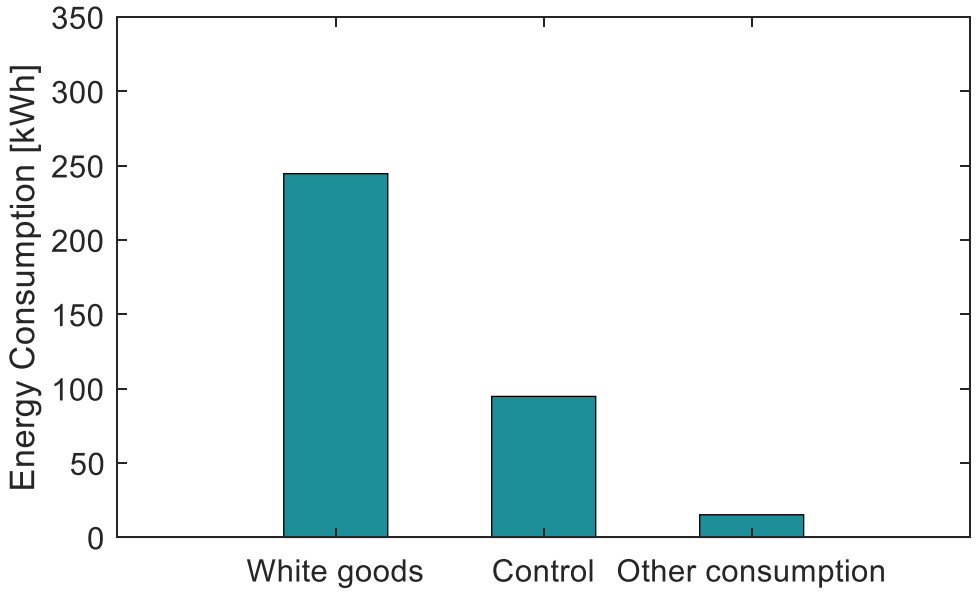

Figure 4: Consumption of electricity during 3 months period time (May, June, July) [kWh]

The energy consumption of white goods includes the kitchen stove, the refrigerator, the Quooker (for production of boiling water), the dishwasher, the dryer and the washing machine. The second column refers to the control of all systems, sensors etc., while the third column includes all the rest.

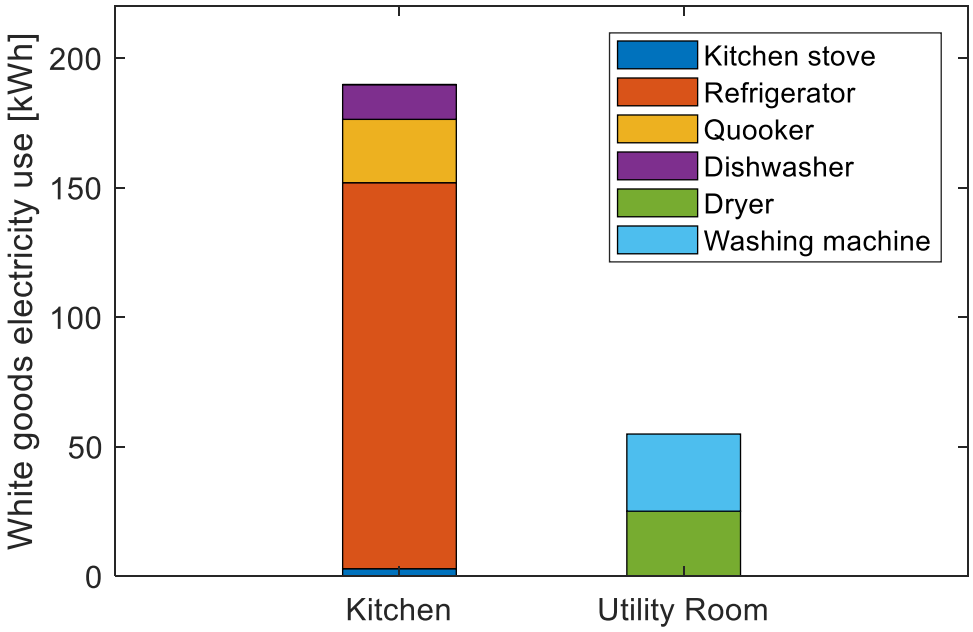

Figure 5: Consumption of electricity of white goods, on room level during 3 months period time (May, June, July) [kWh]

Figure 5 gives the energy consumption for all registered appliances divided in room level.

2.4 Water consumption

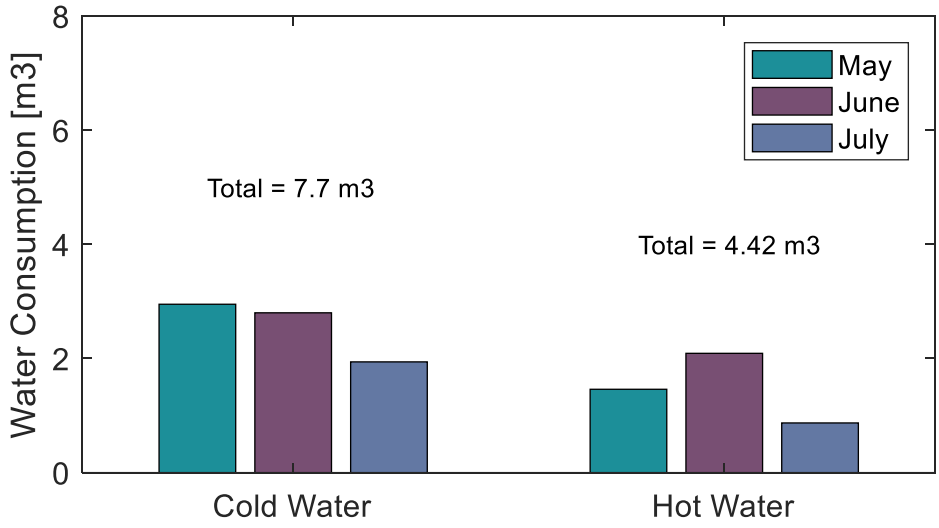

Figure 6: Consumption of cold and hot water [m^3]

The consumption of cold water has been calculated by subtracting the amount of hot water from the total amount of water consumption.

3. Indoor Environment

For the indoor environmental quality is evaluated the thermal and atmospheric indoor climate. More specifically, the examined parameters are the room temperature [°C], CO_2 level [ppm] and relative humidity level [%]. The rooms are examined on a daily level (24 hours), as well as for their expected occupied period. The time from 7:00 to 17:00 is counted as unoccupied, taking into consideration that the occupants are away from home during this period. The following table sums up the corresponding periods for each type of room.

	Scenario 1	Scenario 2
Living Room	24 h	Day: 17 - 23
Kitchen	24 h	Day: 17 - 23
Master bedroom	24 h	Night: 23 - 7

3.1 Thermal indoor environment

The thermal criteria are assessed according to the comfort categories given by the standards DS/EN 15251. The following table shows the temperature ranges for the three categories, assuming an activity level of 1.2 met (sedentary activity).

Activity level [met]		1.2		
Category		I	II	III
Operative temperature [°C]	Summer	24.5 ± 1.0	24.5 ± 1.5	24.5 ± 2.5
	Winter	22.0 ± 1.0	22.0 ± 2.0	22.0 ± 3.0

The recommended criteria for acceptable deviations for the thermal environment, for Category II, are presented in the following table.

		Max. deviation	
	Criteria	Monthly	Yearly
General Assessment	Class II	3 & 5 %	3 & 5 %
Overheating	25 °C	10 %	10 %
	27 °C	-	100 h
	28 °C	-	25 h
Under heating	20 °C	-	100 h
	19 °C	-	25 h

The distribution of hours in each of the three categories is given in percentages, in form of bar charts, specifying whether the room temperature lies on the low or high part of the scale, for summer and winter period, respectively.

IV-	III-	II-	I	II+	III+	IV+
t < 22	22 ≤ t < 23	23 ≤ t < 23.5	23.5 ≤ t ≤ 25.5	25.5 < t ≤ 26	26 < t ≤ 27	27 < t
t < 19	19 ≤ t < 20	20 ≤ t < 21	21 ≤ t ≤ 23	23 < t ≤ 24	24 < t ≤ 25	25 < t

3.1.1 May

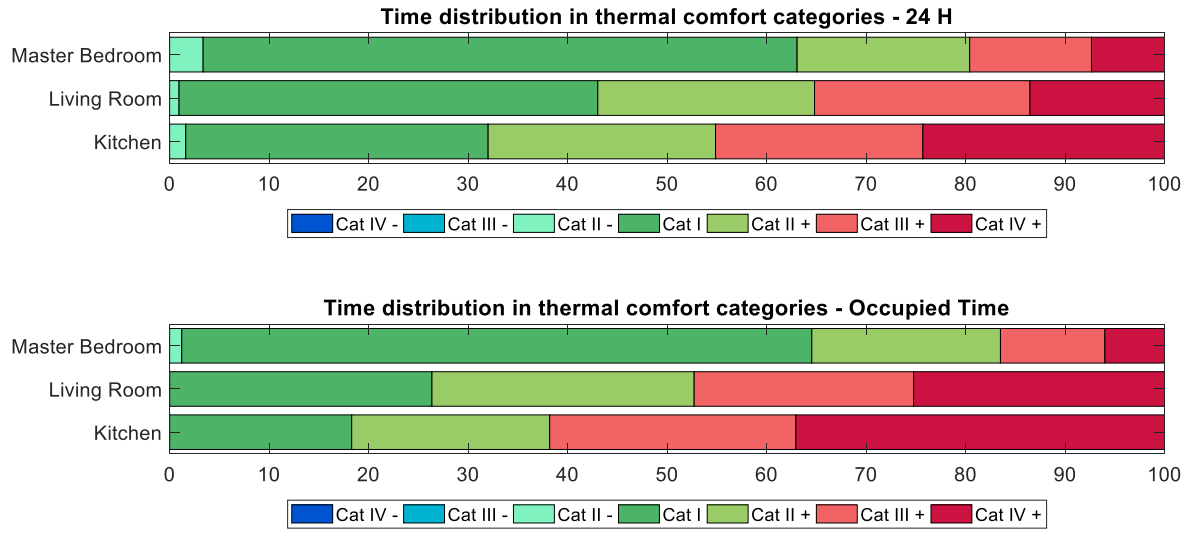

Figure 7: Percentage of time in each Category for tempeature during May

3.1.2 June

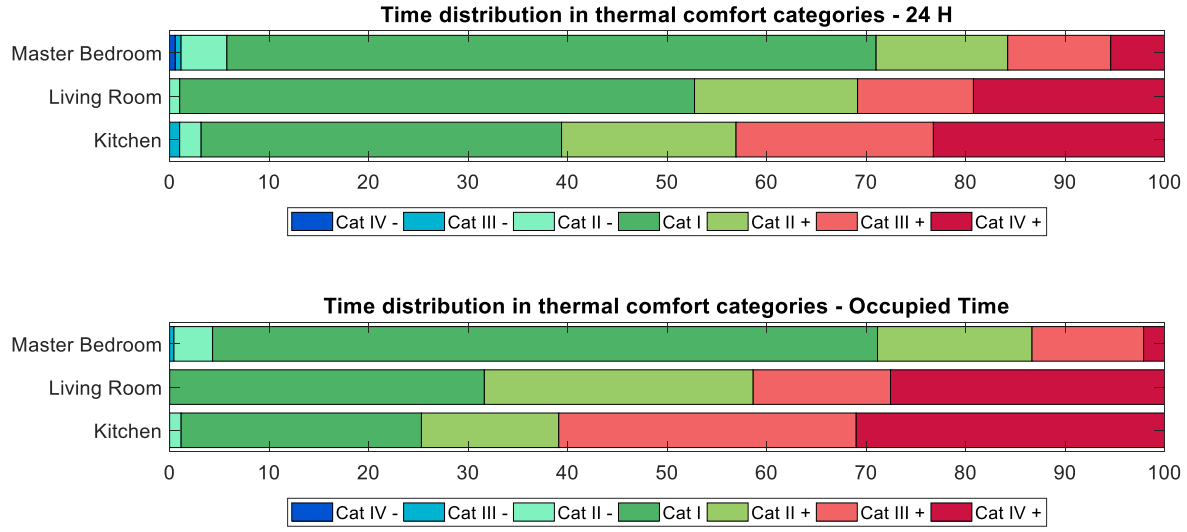

Figure 8: Percentage of time in each Category for tempeature during June

3.1.3 July

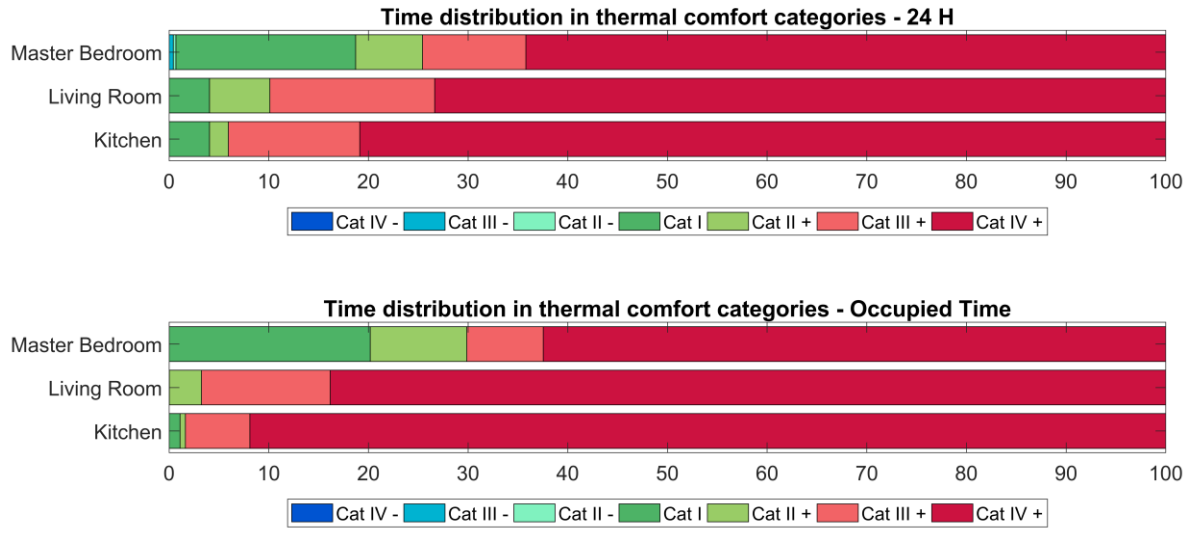

Figure 9: Percentage of time in each Category for tempeature during July

3.1.4 Entire period (May, June, July)

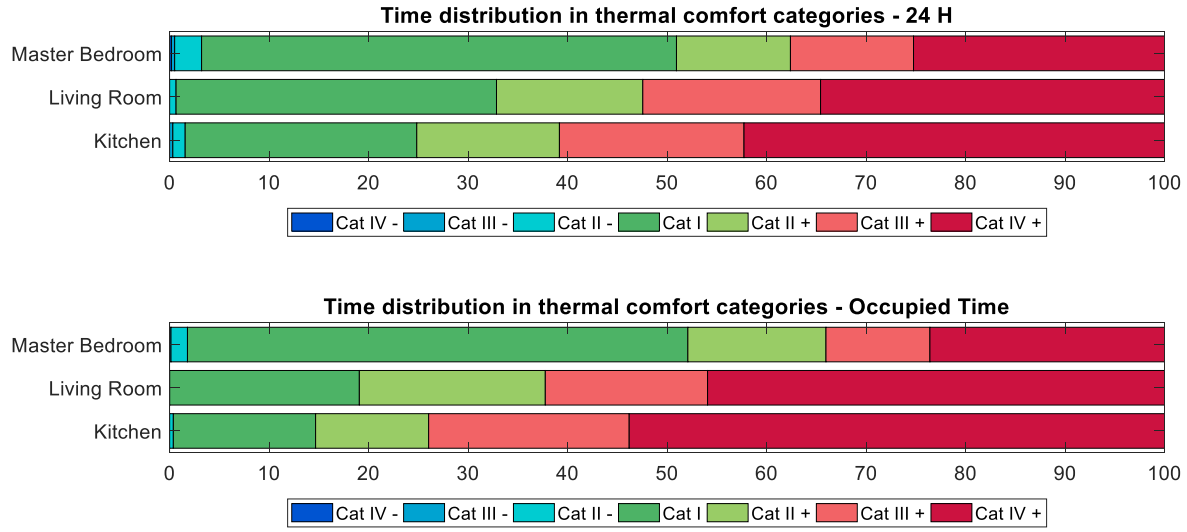

Figure 10: Percentage of time in each Category for tempeature during 3 months period time (May, June, July)

3.2 Atmospheric indoor environment

The indoor air quality is also assessed based on the comfort categories suggested by the standards DS/EN 15251. On the following tables are given the acceptable ranges for CO_2 level and relative humidity, respectively.

Category	Corresponding CO_2 above outdoors level [ppm]
I	350
II	500
III	800
IV	> 800

Category	Design relative humidity for dehumidification [%]	Design relative humidity for humidification [%]
I	50	30
II	60	25
III	70	20
IV	>70	<20

The outdoor CO_2 level is taken as a standard value of 400 ppm and not as the minimum registered value by the sensors in each room. This was decided based on the observation that occasionally some of the sensors would register some unrealistically small values. Actions have been taken in order to verify the proper operation of the sensors and eventually to calibrate or replace them. Therefore, it should be kept in mind that there is some uncertainty concerning the presented results for the CO_2 level.

Next table shows the recommended criteria for acceptable deviations for the atmospheric environment, for Category II.

		Max. deviation
	Criteria	Monthly
CO_2	Category II	3 & 5 %
	Category II	8 h in a row
Relative Humidity	Category II	3 & 5 %
	Category II	24 h in a row
	RH< 45%	-
	RH> 75%	1%

3.2.1 May

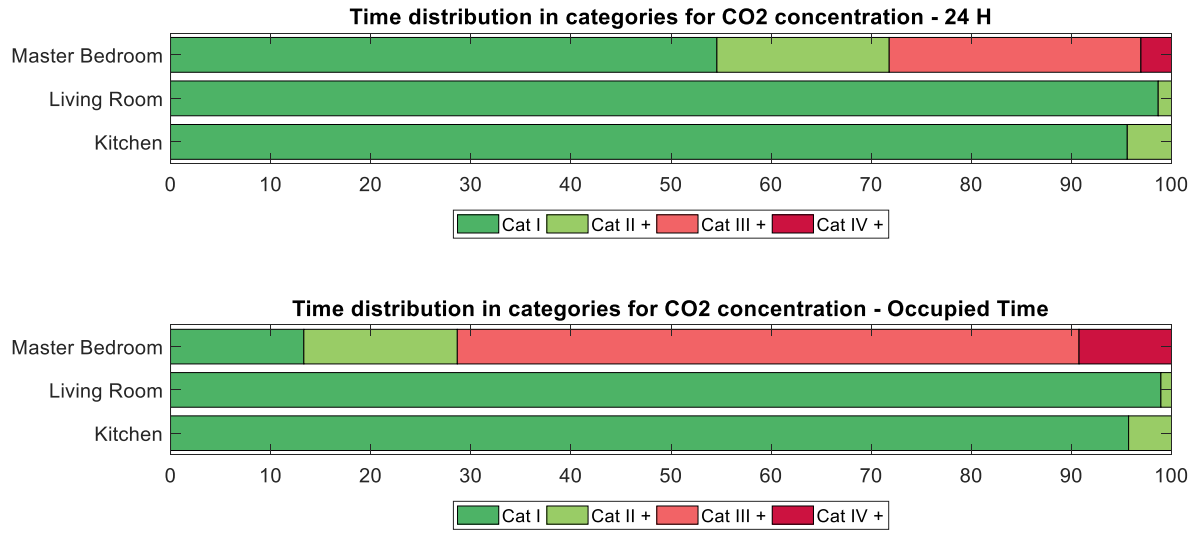

Figure 11: Percentage of time in each Category for CO_2 level during May

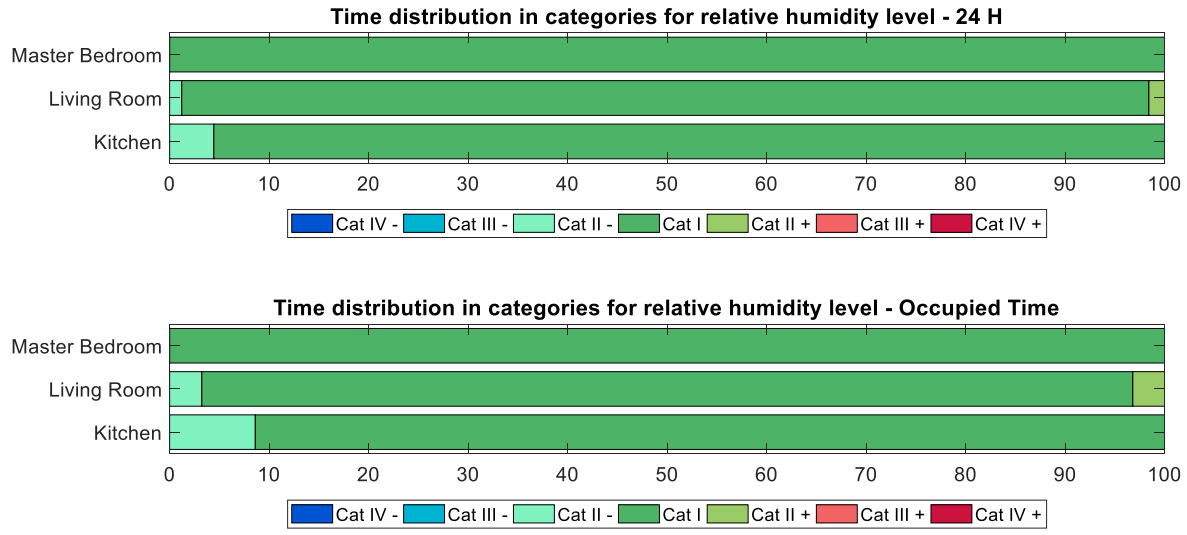

Figure 12: Percentage of time in each Category for relative humidity during May

3.2.2 June

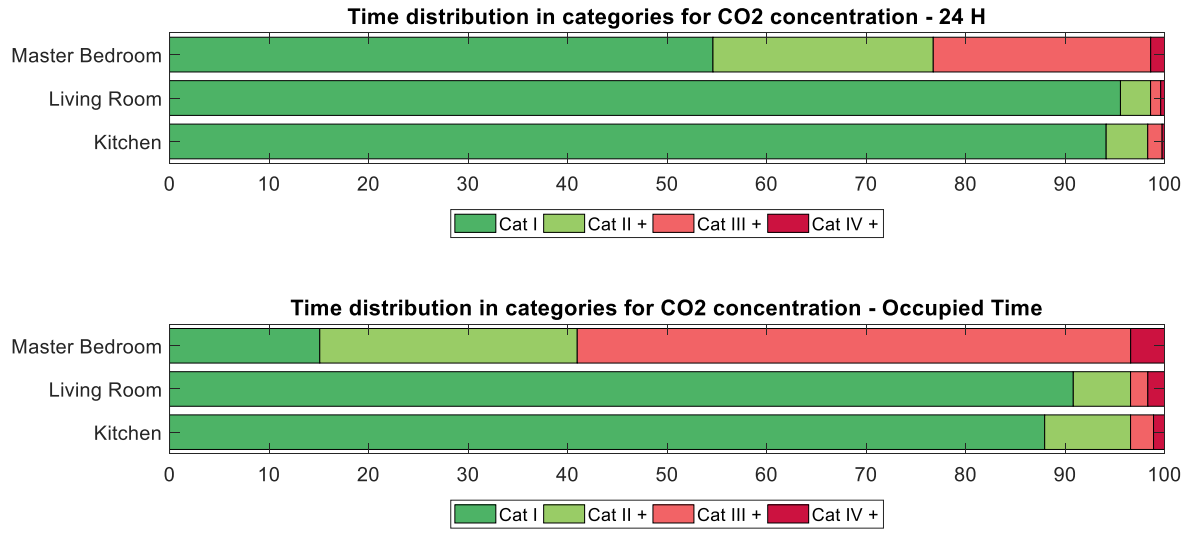

Figure 13: Percentage of time in each Category for CO_2 level during June

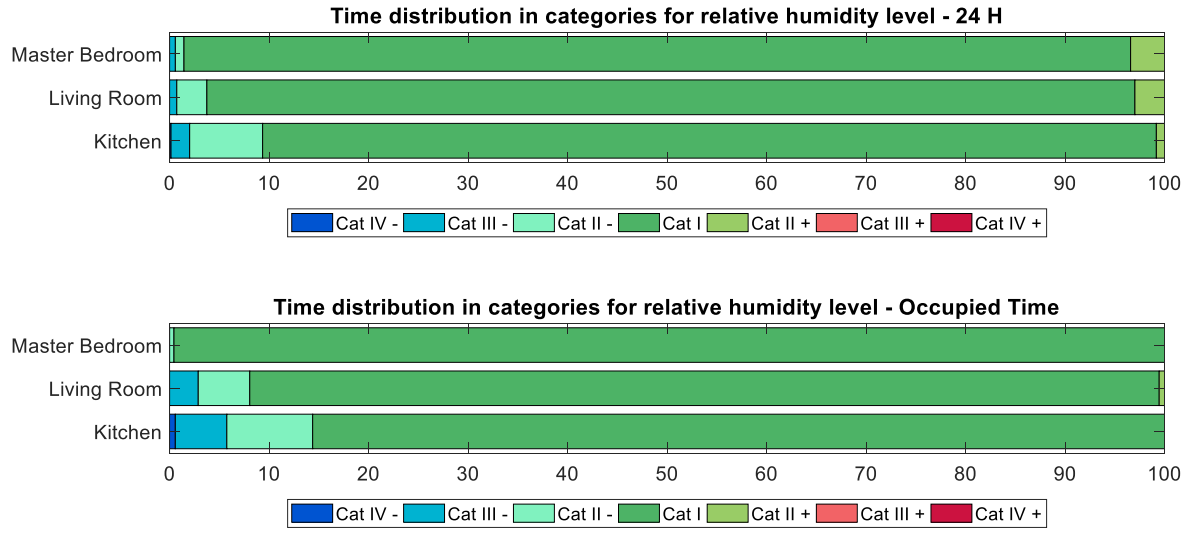

Figure 14: Percentage of time in each Category for relative humidity during June

3.2.3 July

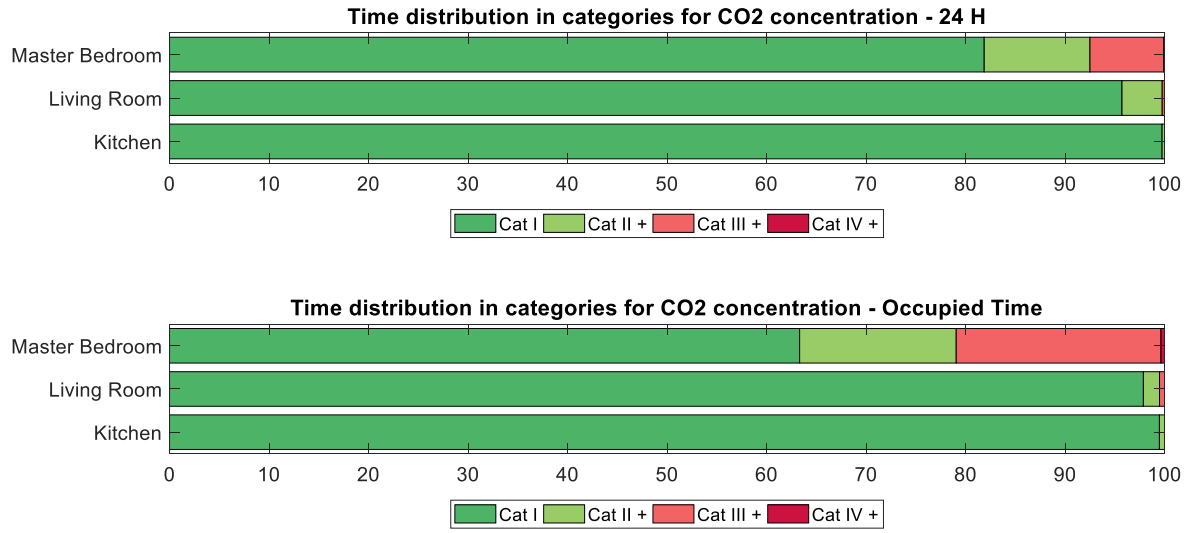

Figure 15: Percentage of time in each Category for CO_2 level during July

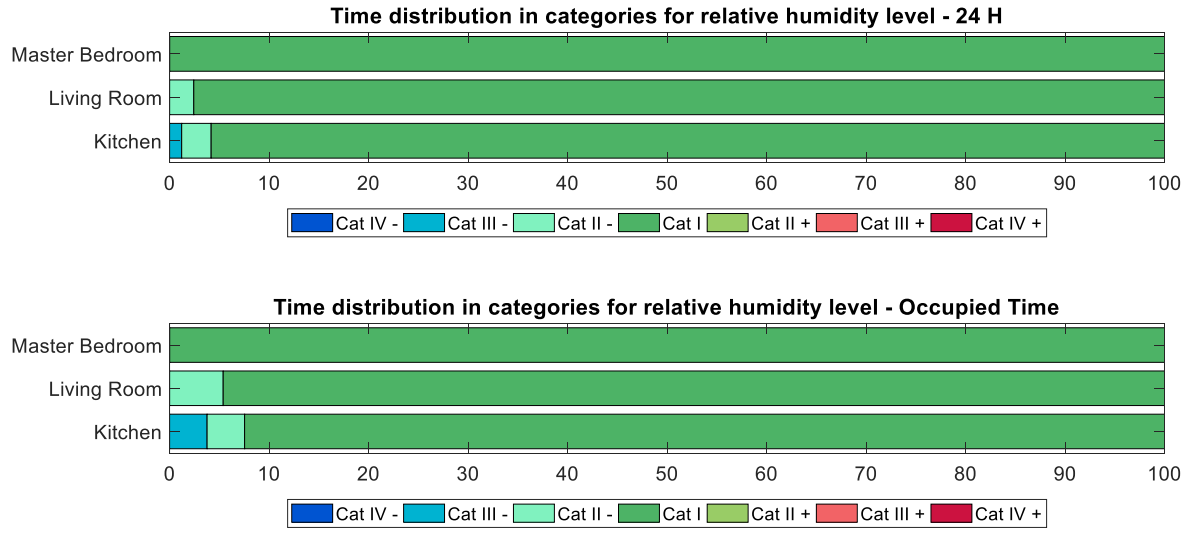

Figure 16: Percentage of time in each Category for relative humidity during July

3.2.4 *Entire period (May, June, July)*

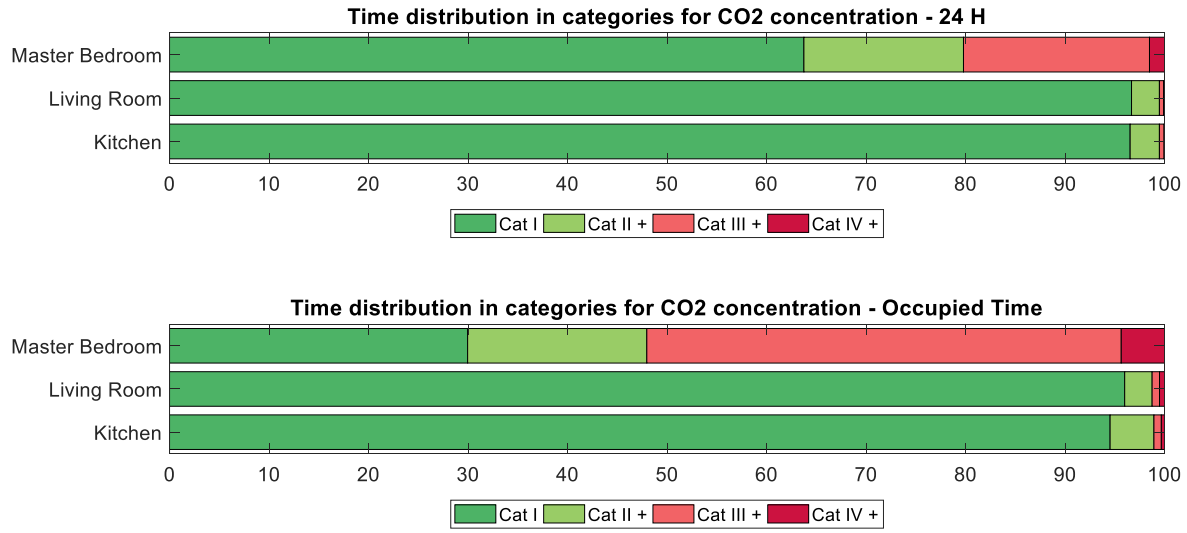

Figure 17: Percentage of time in each Category for CO_2 level during 3 months period time (May, June, July)

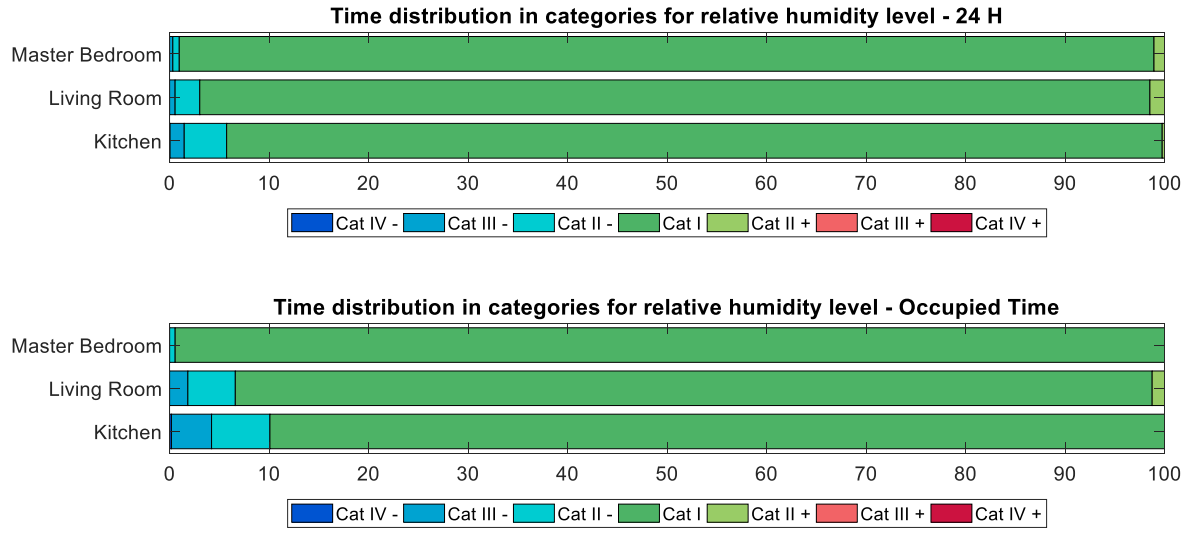

Figure 18: Percentage of time in each Category for relative humidity during 3 months period time (May, June, July)

4. Annex

4.1 May

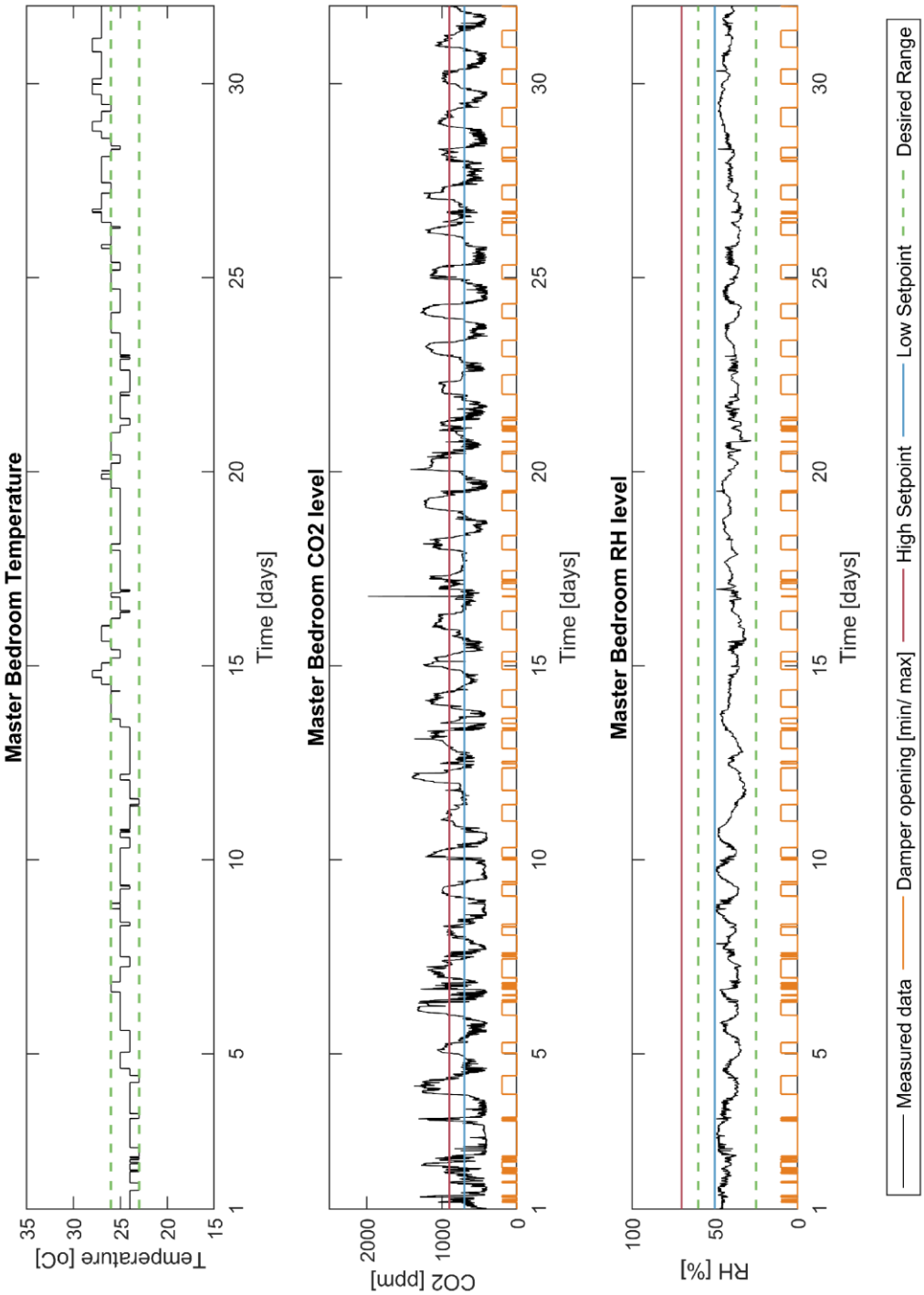

Figure 19: Graphs for temperature, CO2 level and relative humidity during the month of May– Master Bedroom

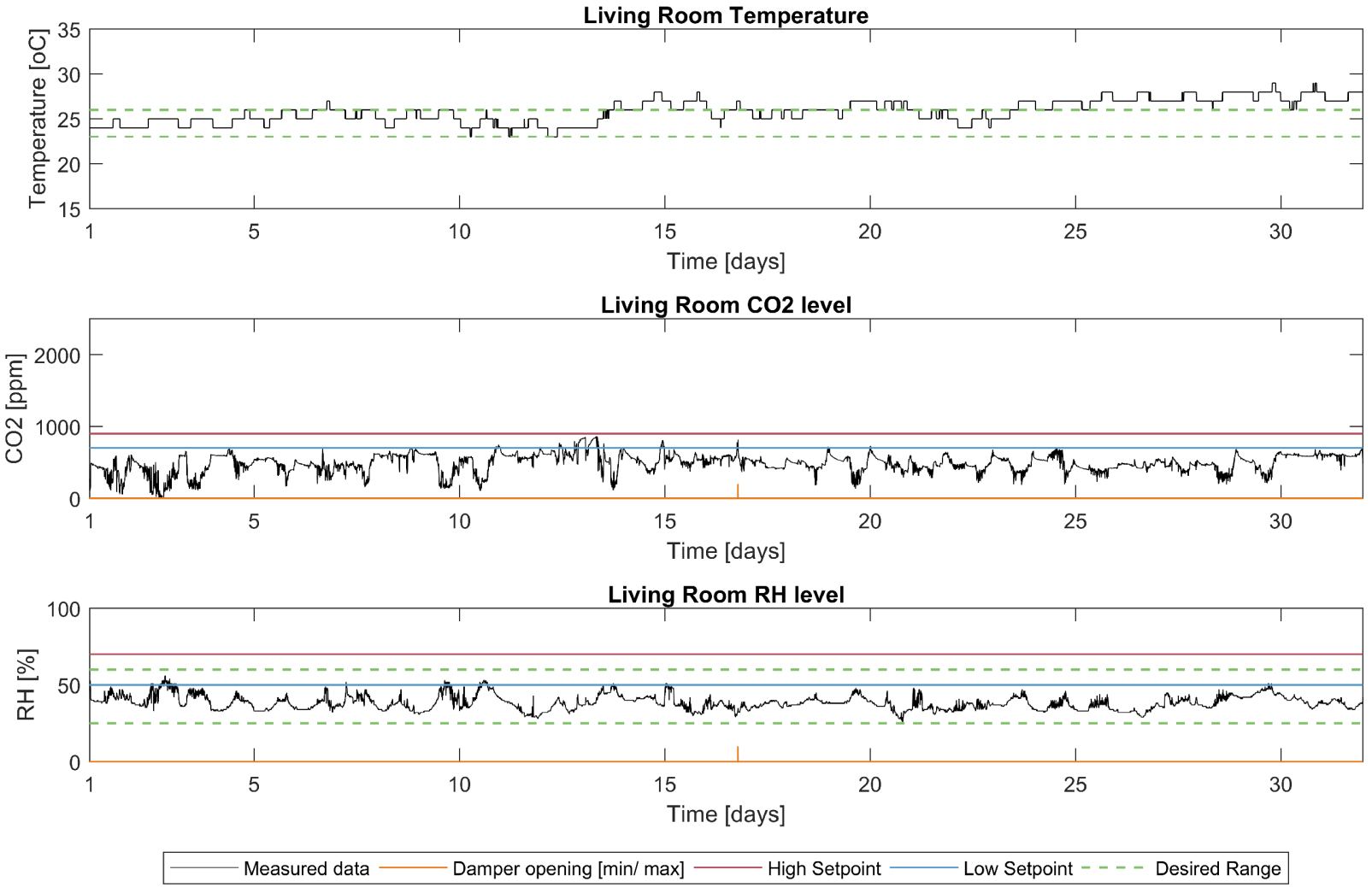

Figure 20: Graphs for temperature, CO_2 level and relative humidity during the month of May – Living Room

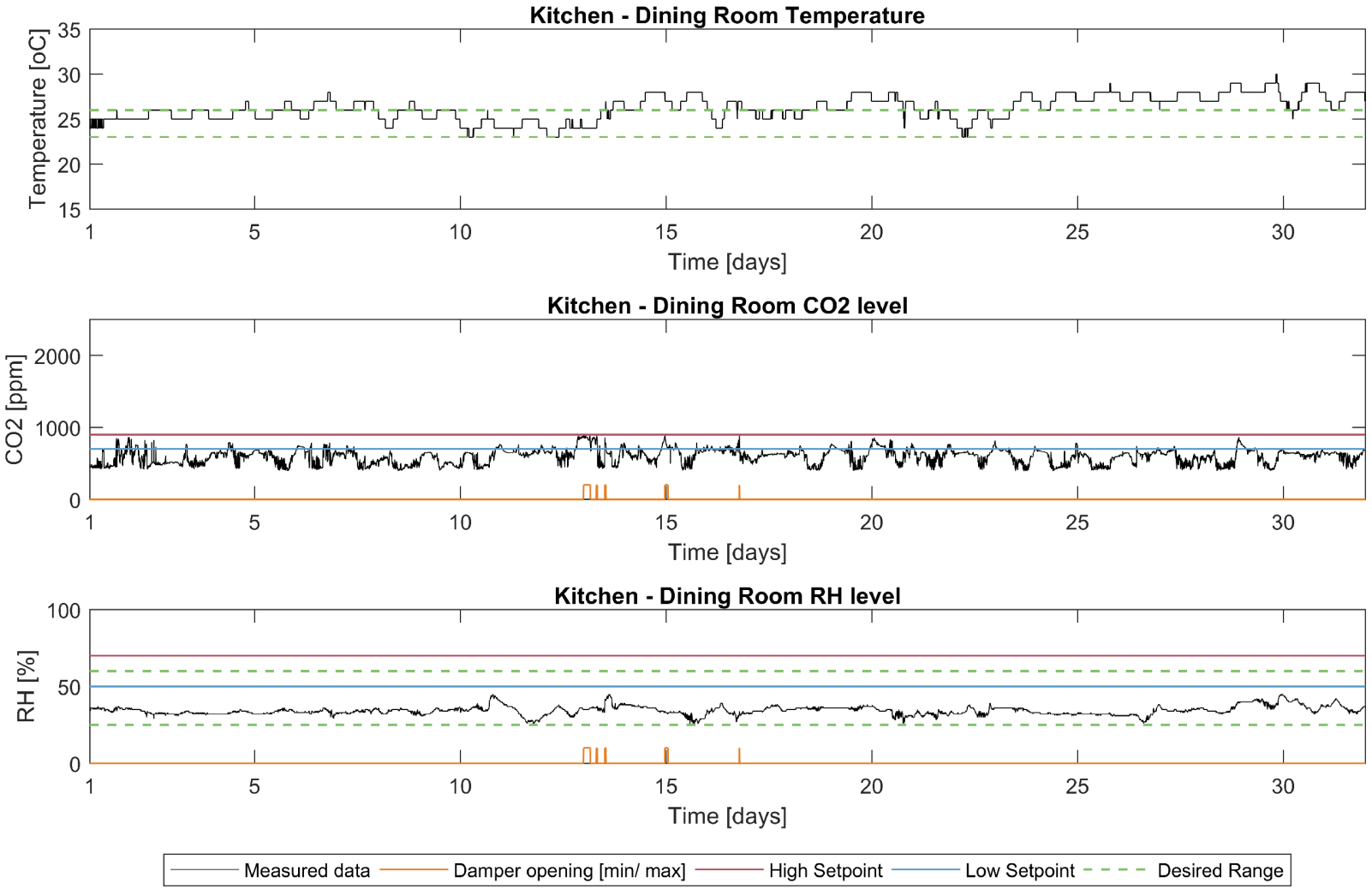

Figure 21: Graphs for temperature, CO_2 level and relative humidity during the month of May – Kitchen/ Dining Room

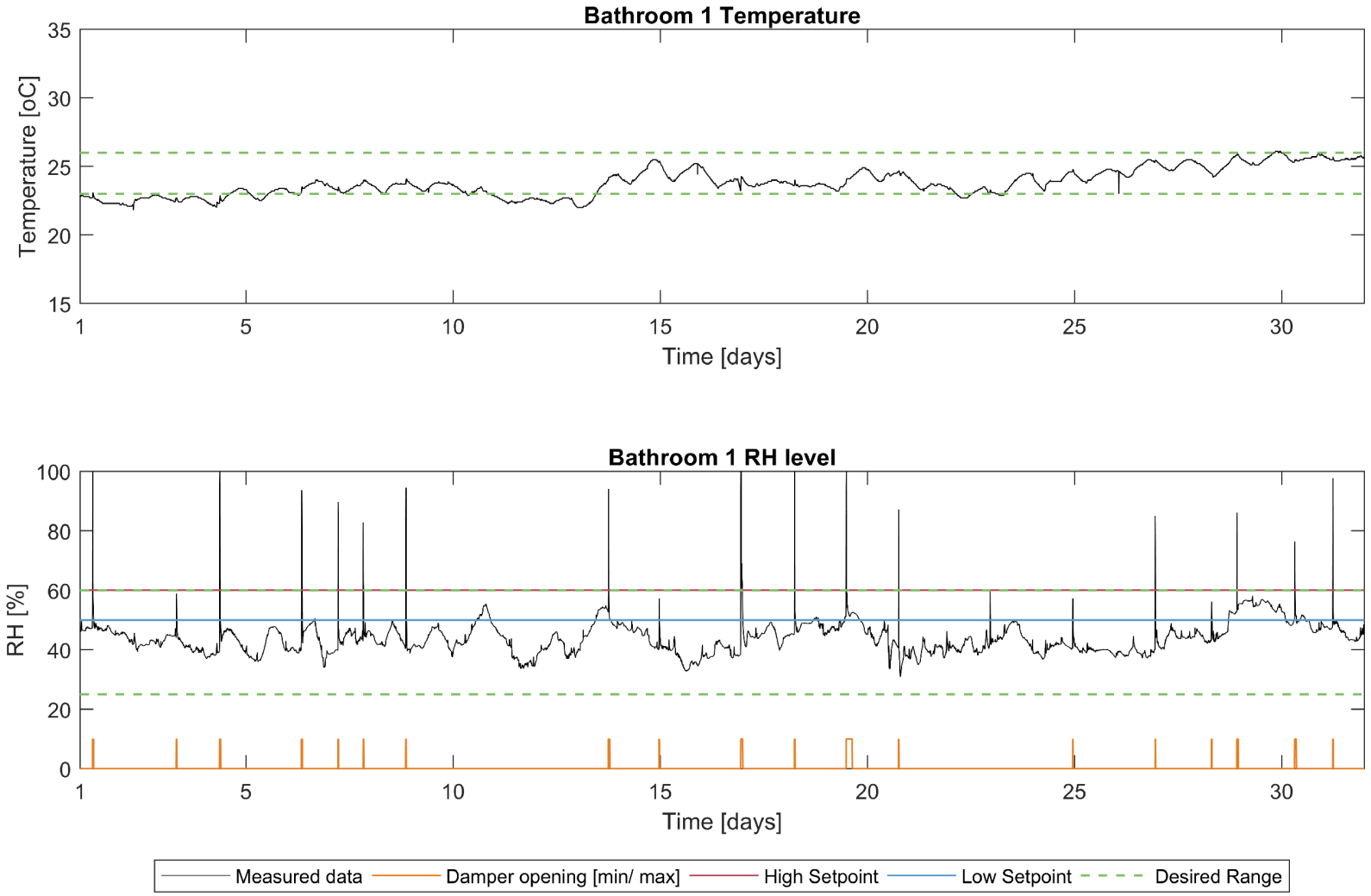

Figure 22: Graphs for temperature, CO_2 level and relative humidity during the month of May – Bathroom 1

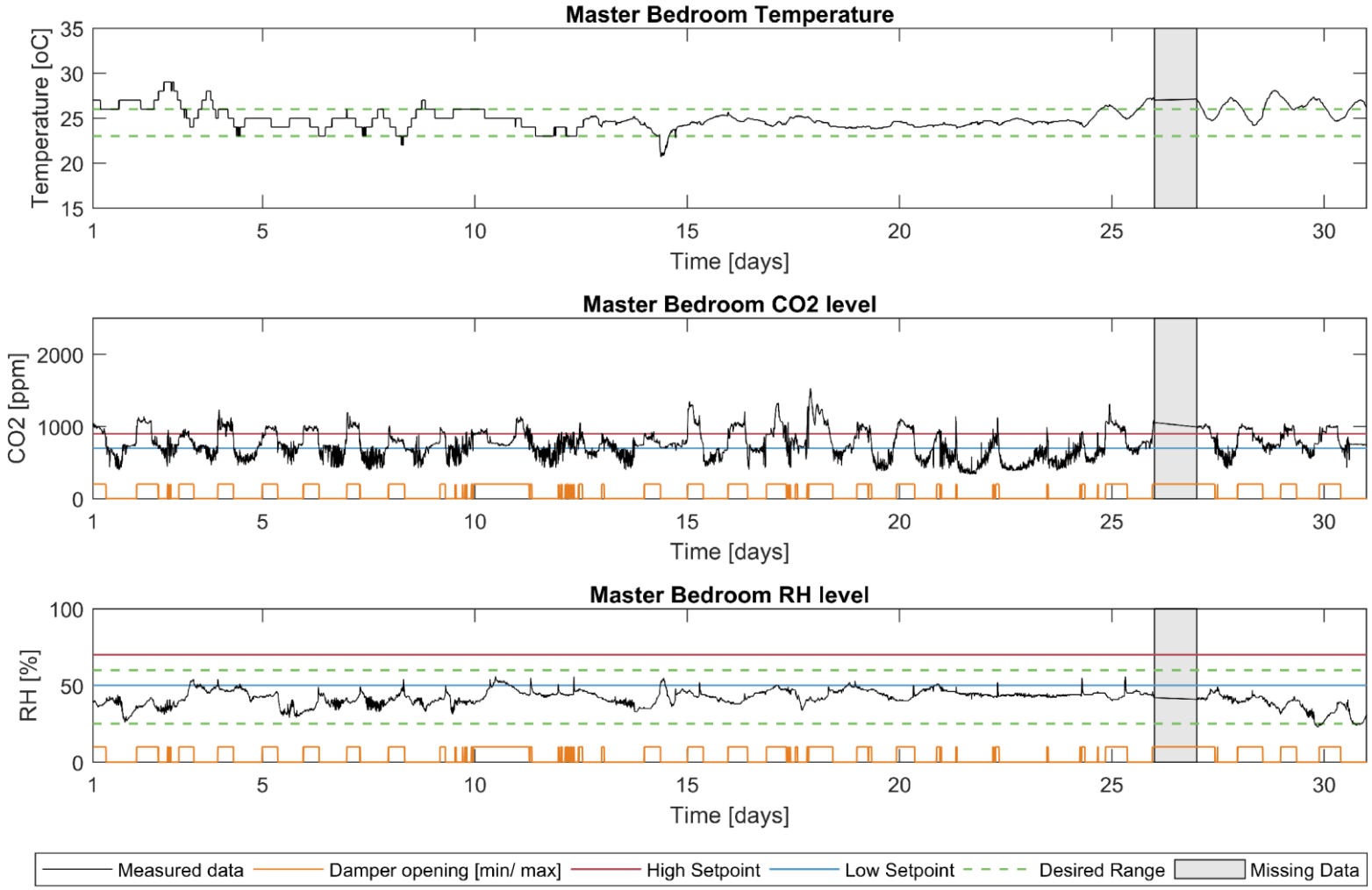

Figure 23: Graphs for temperature, CO_2 level and relative humidity during the month of June – Master Bedroom

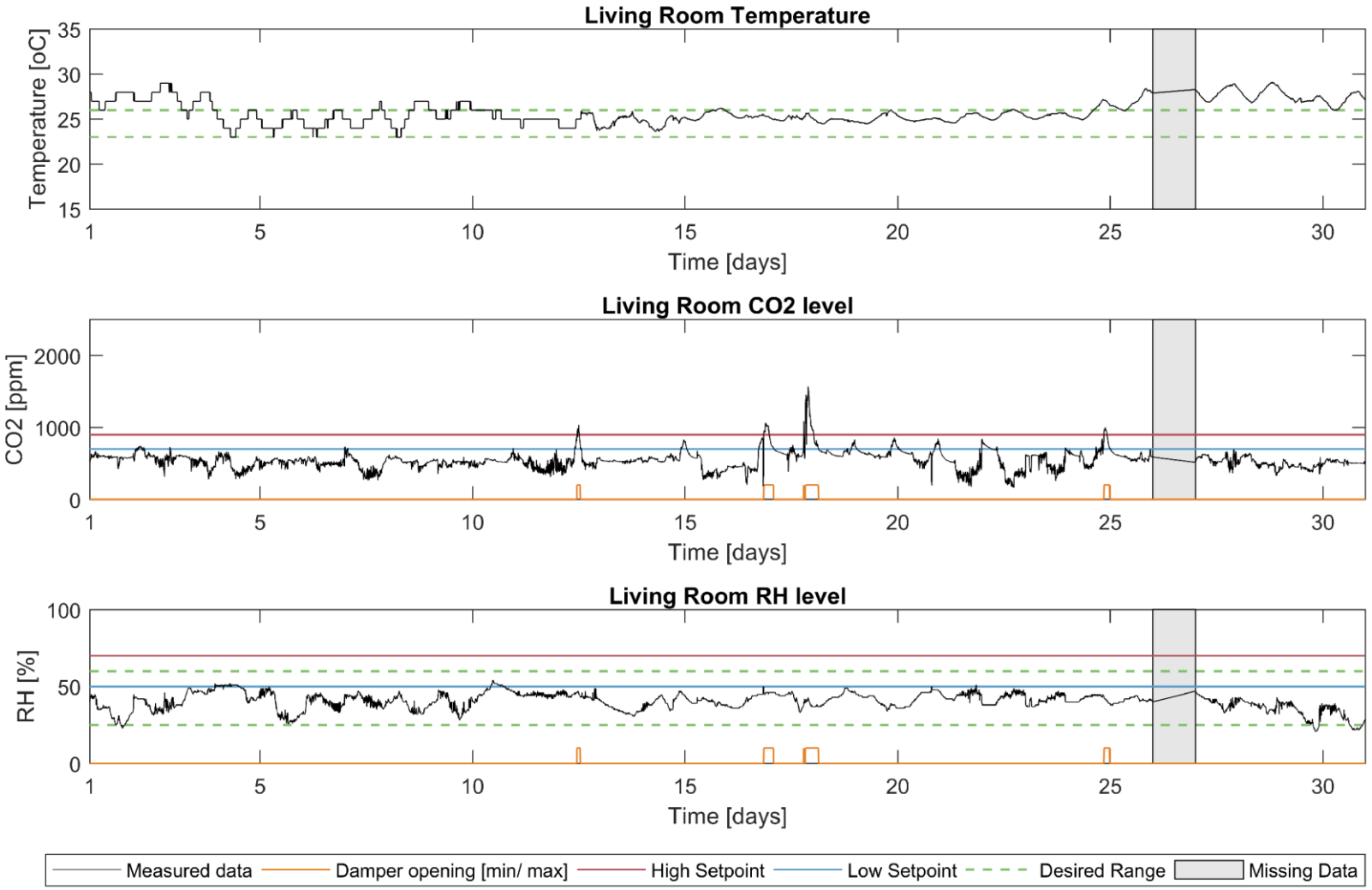

Figure 24: Graphs for temperature, CO_2 level and relative humidity during the month of June – Living Room

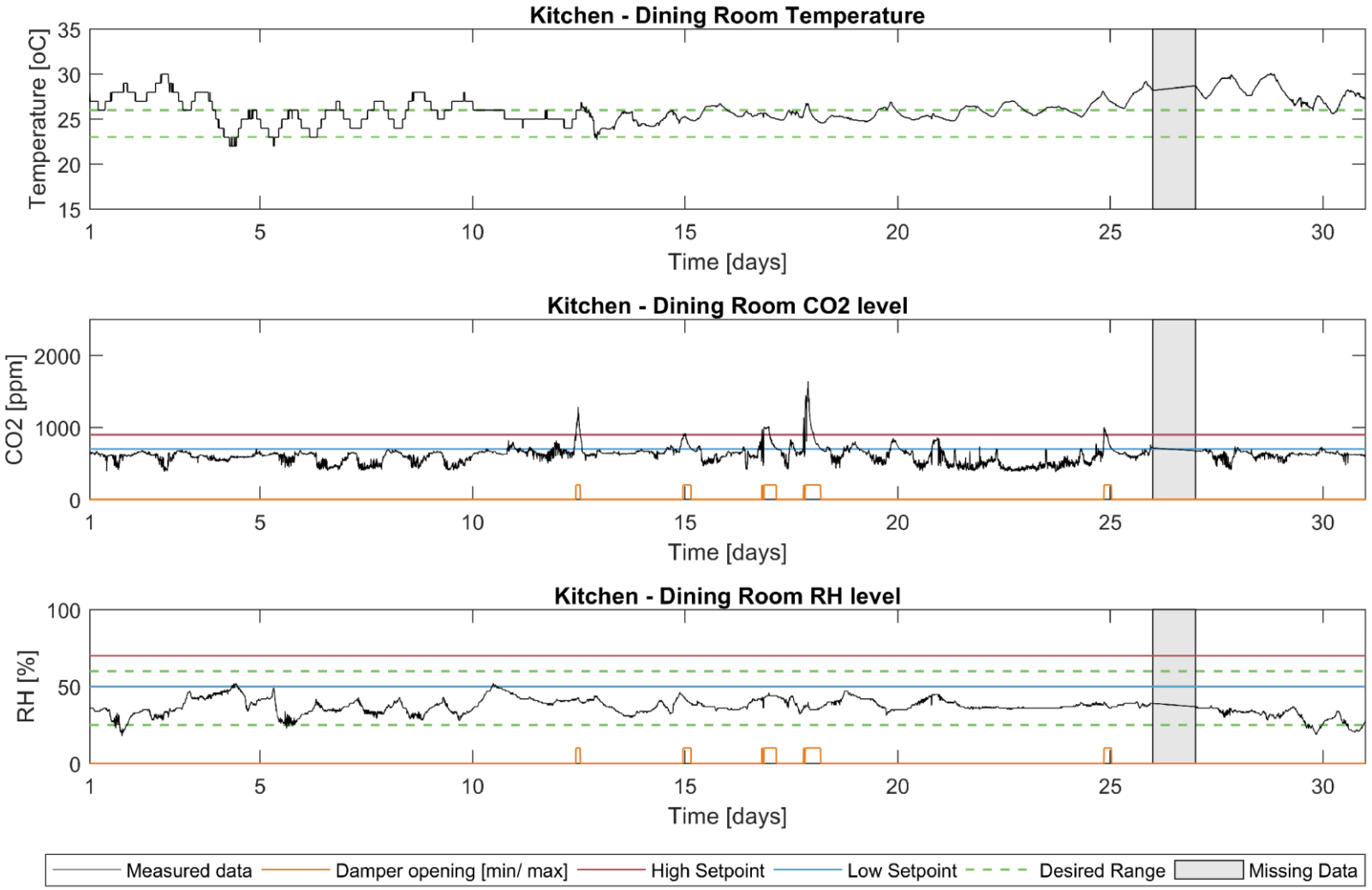

Figure 25: Graphs for temperature, CO_2 level and relative humidity during the month of June– Kitchen/ Dining Room

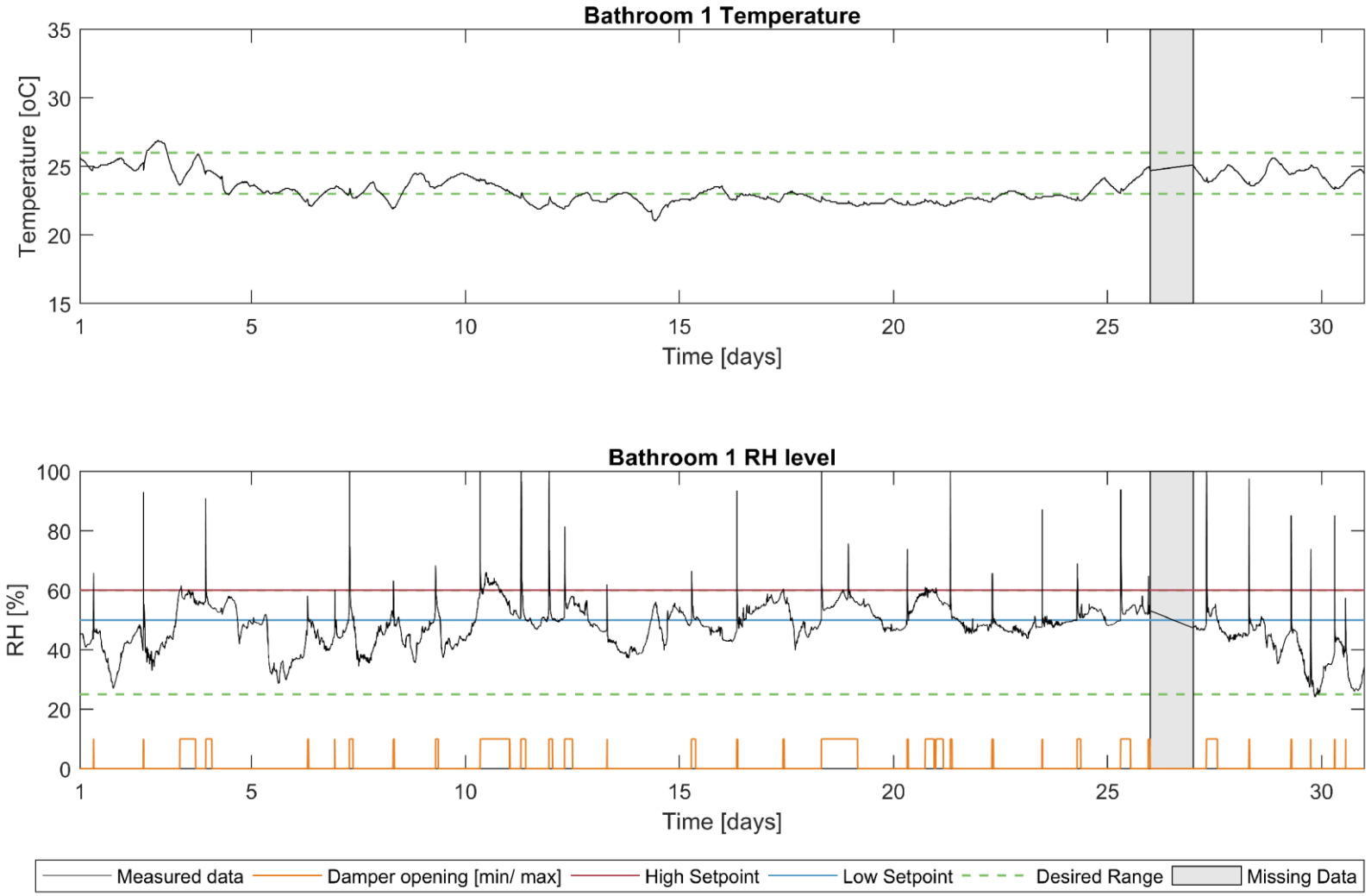

Figure 26: Graphs for temperature, CO_2 level and relative humidity during the month of June – Bathroom 1

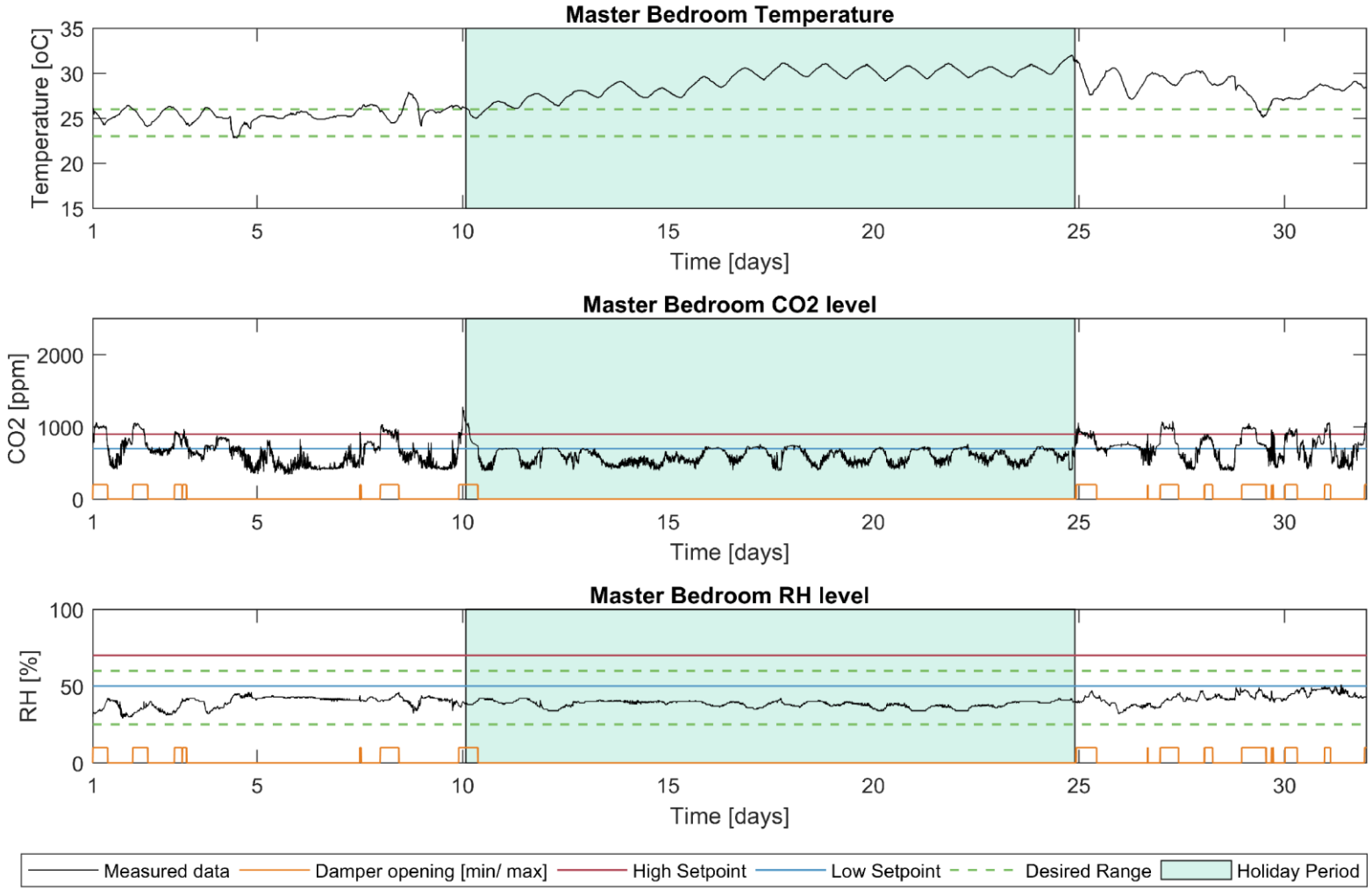

Figure 27: Graphs for temperature, CO_2 level and relative humidity during the month of July – Master Bedroom

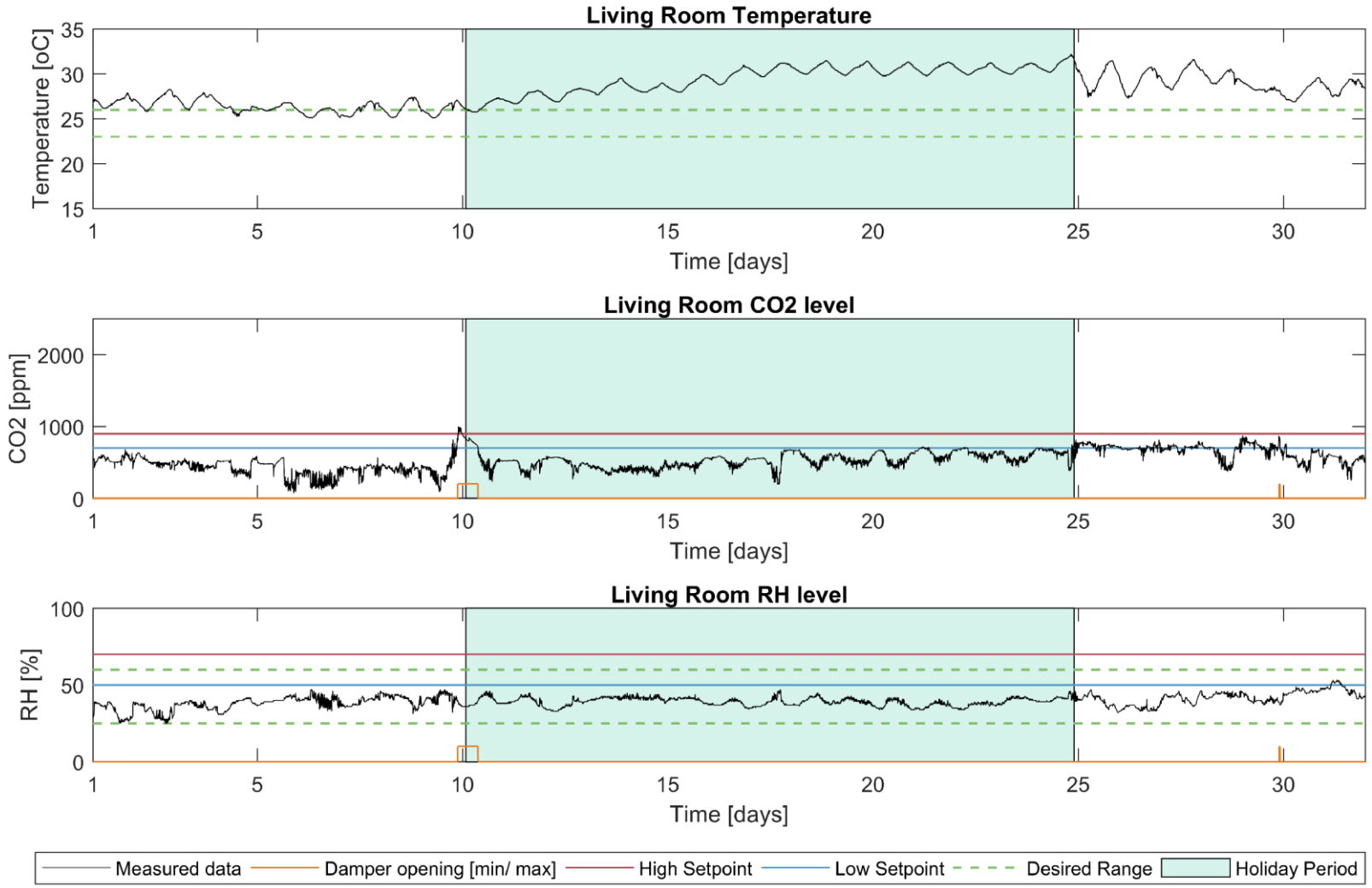

Figure 28: Graphs for temperature, CO_2 level and relative humidity during the month of July – Living Room

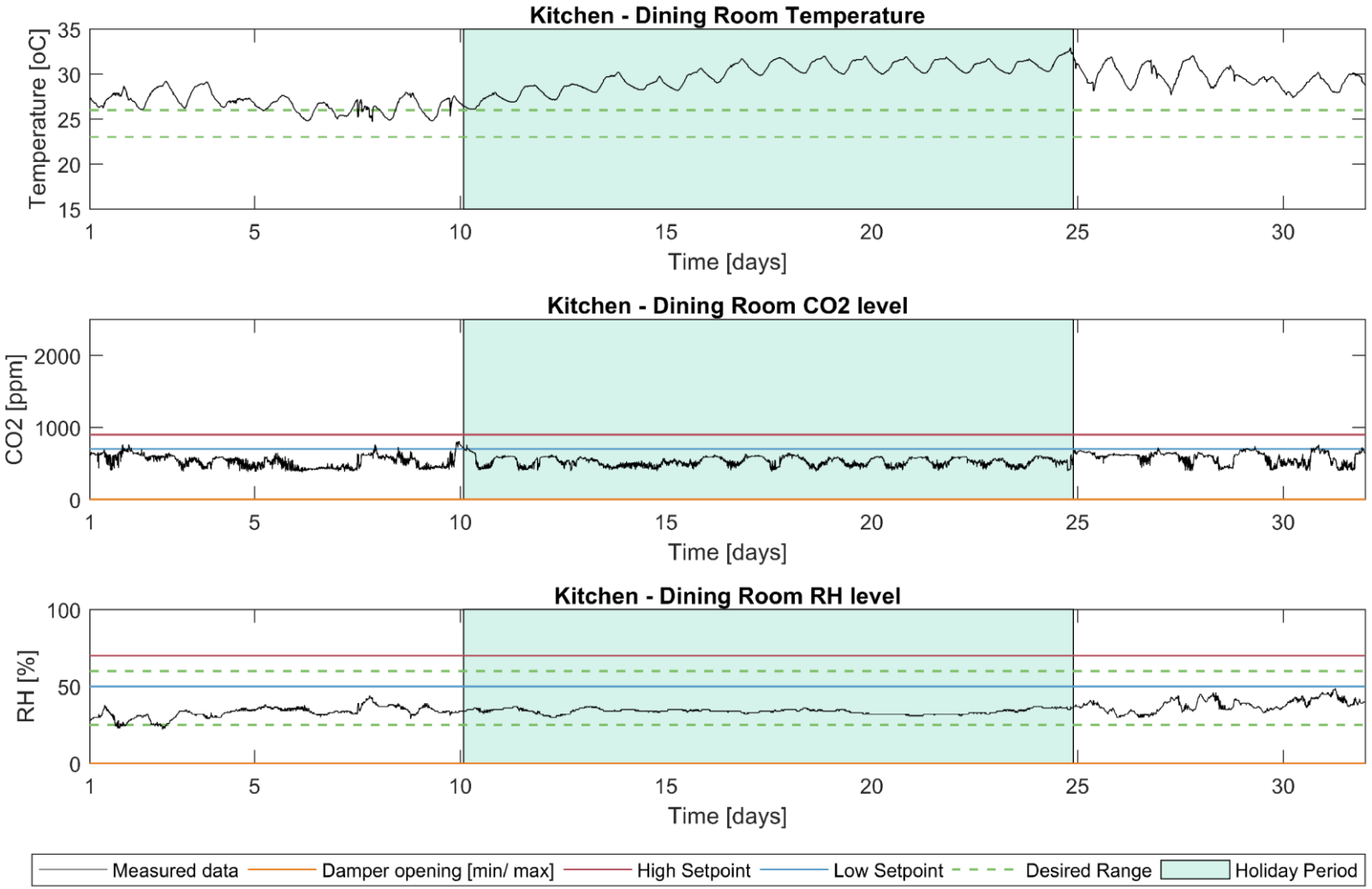

Figure 29: Graphs for temperature, CO_2 level and relative humidity during the month of July – Kitchen/ Dining Room

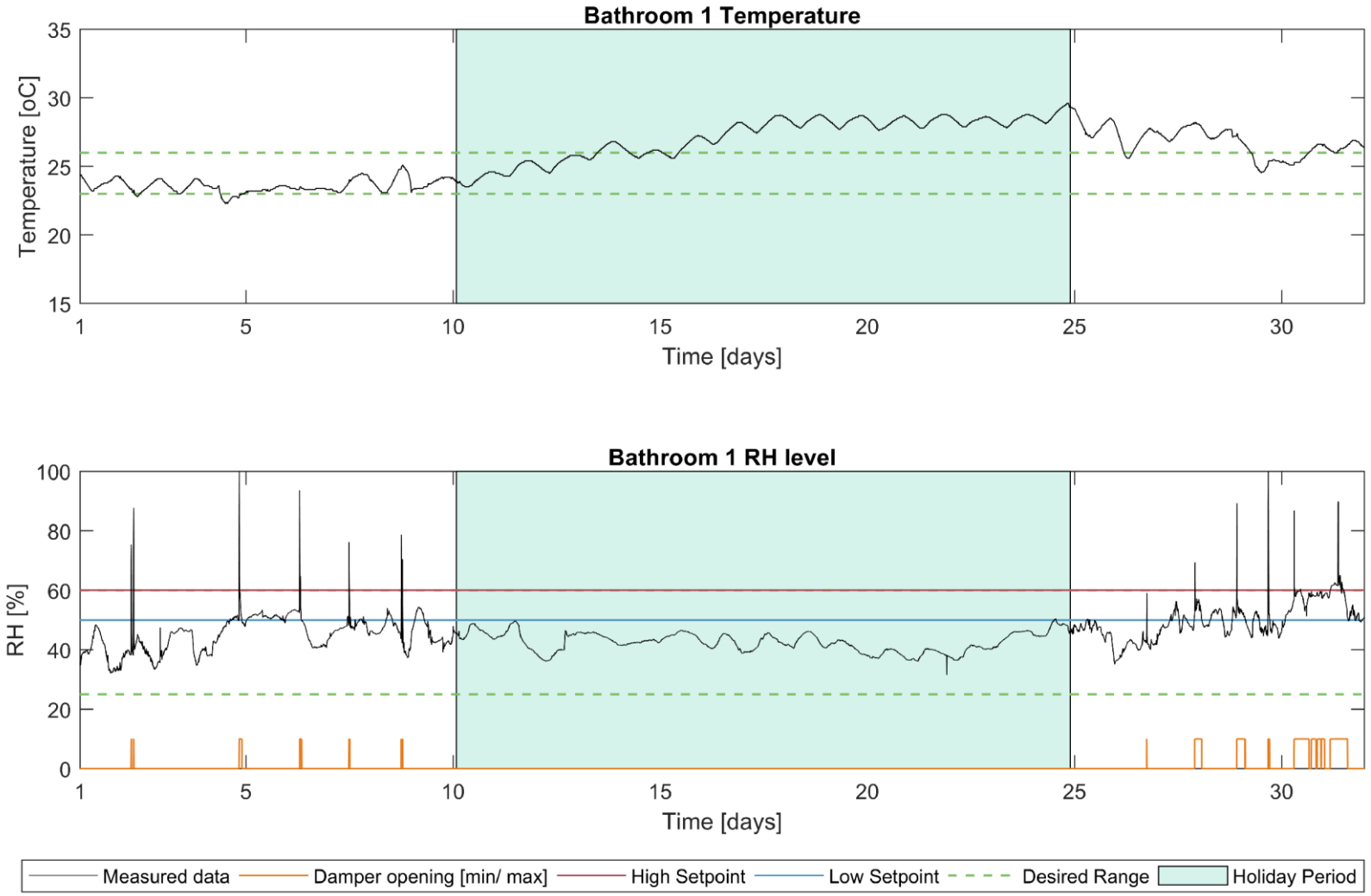

Figure 30: Graphs for temperature, CO_2 level and relative humidity during the month of July – Bathroom 1

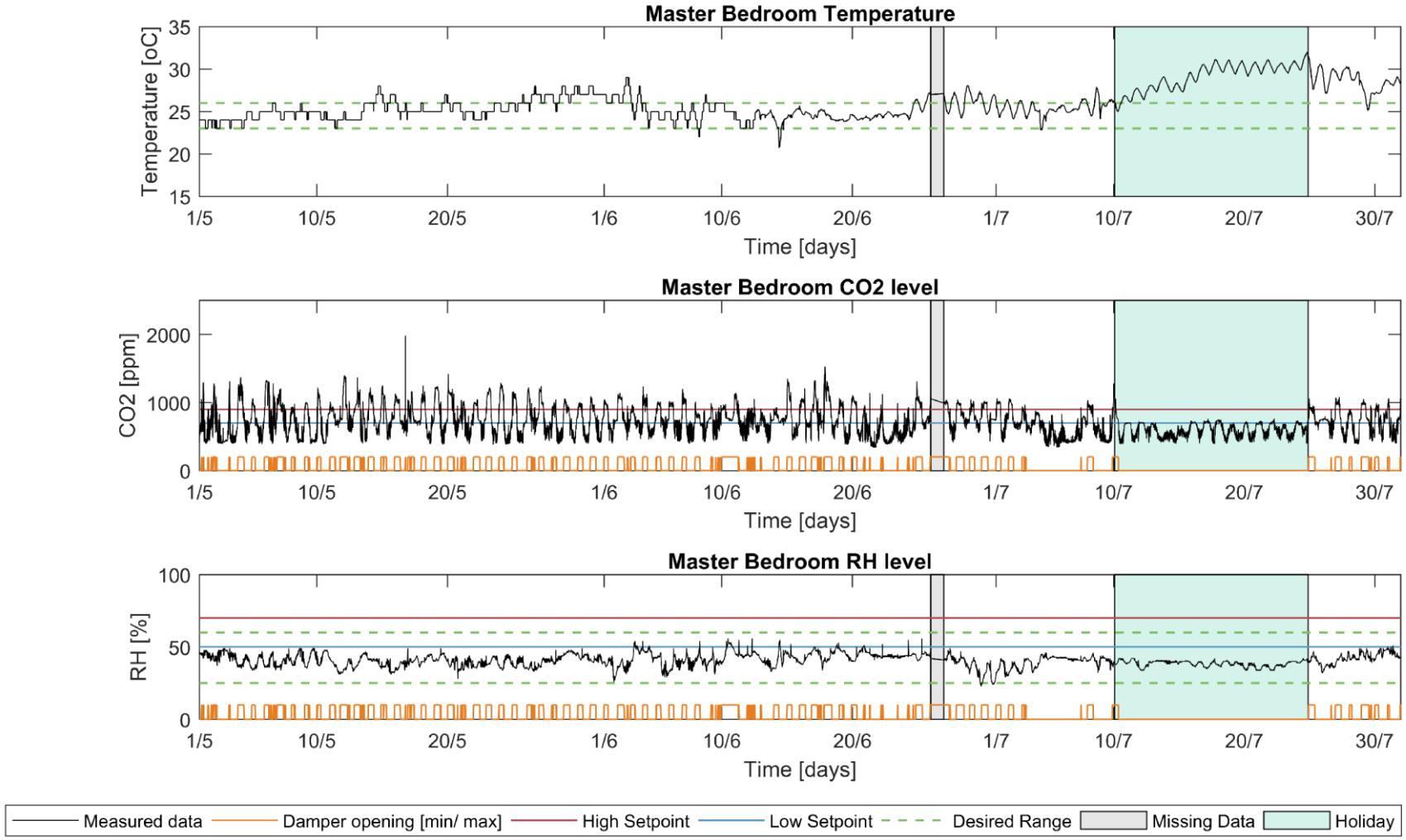

Figure 31: Graphs for temperature, CO_2 level and relative humidity during the 3 months period (May, June, July) – Master Bedroom

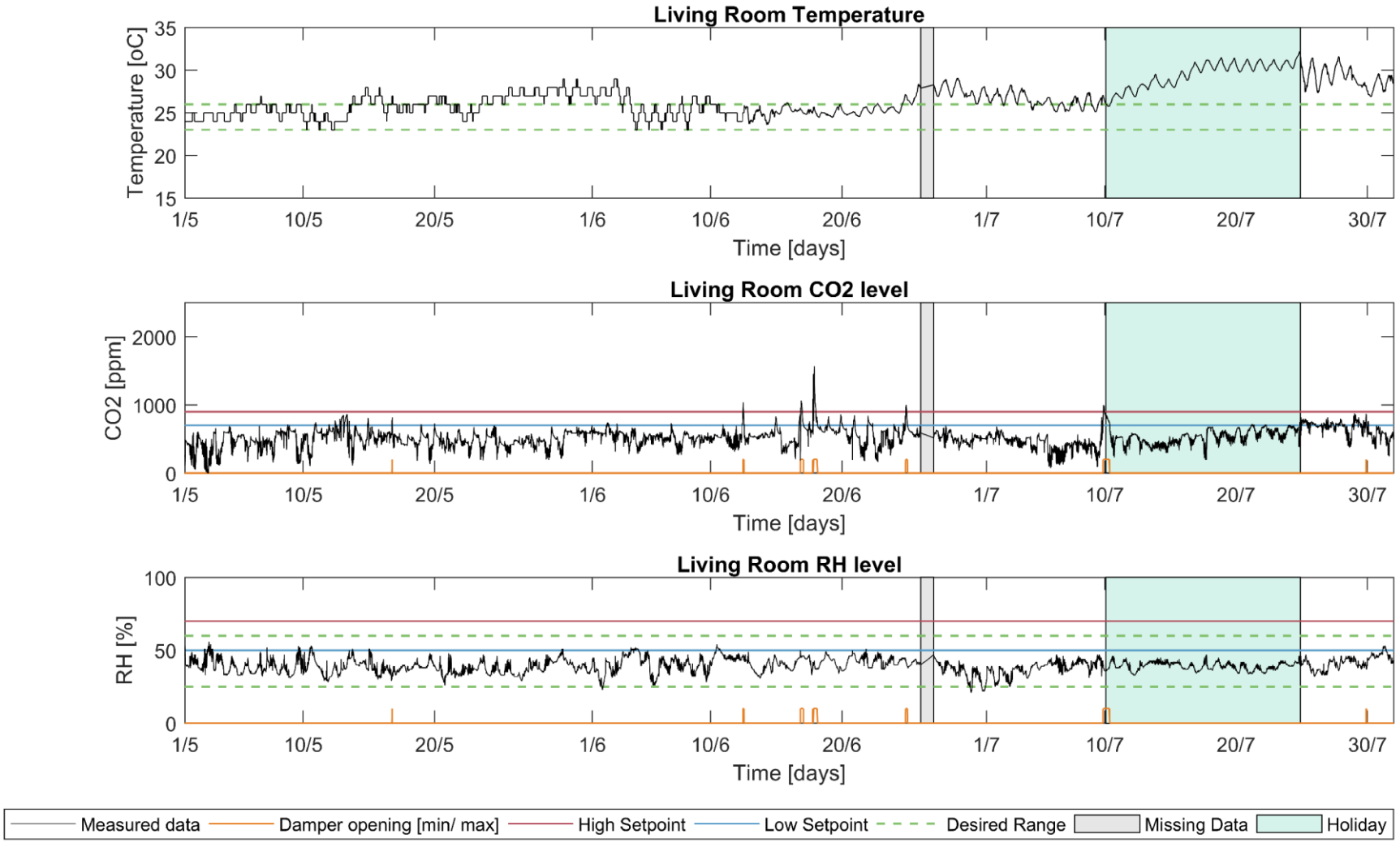

Figure 32: Graphs for temperature, CO_2 level and relative humidity during the 3 months period (May, June, July) – Living Room

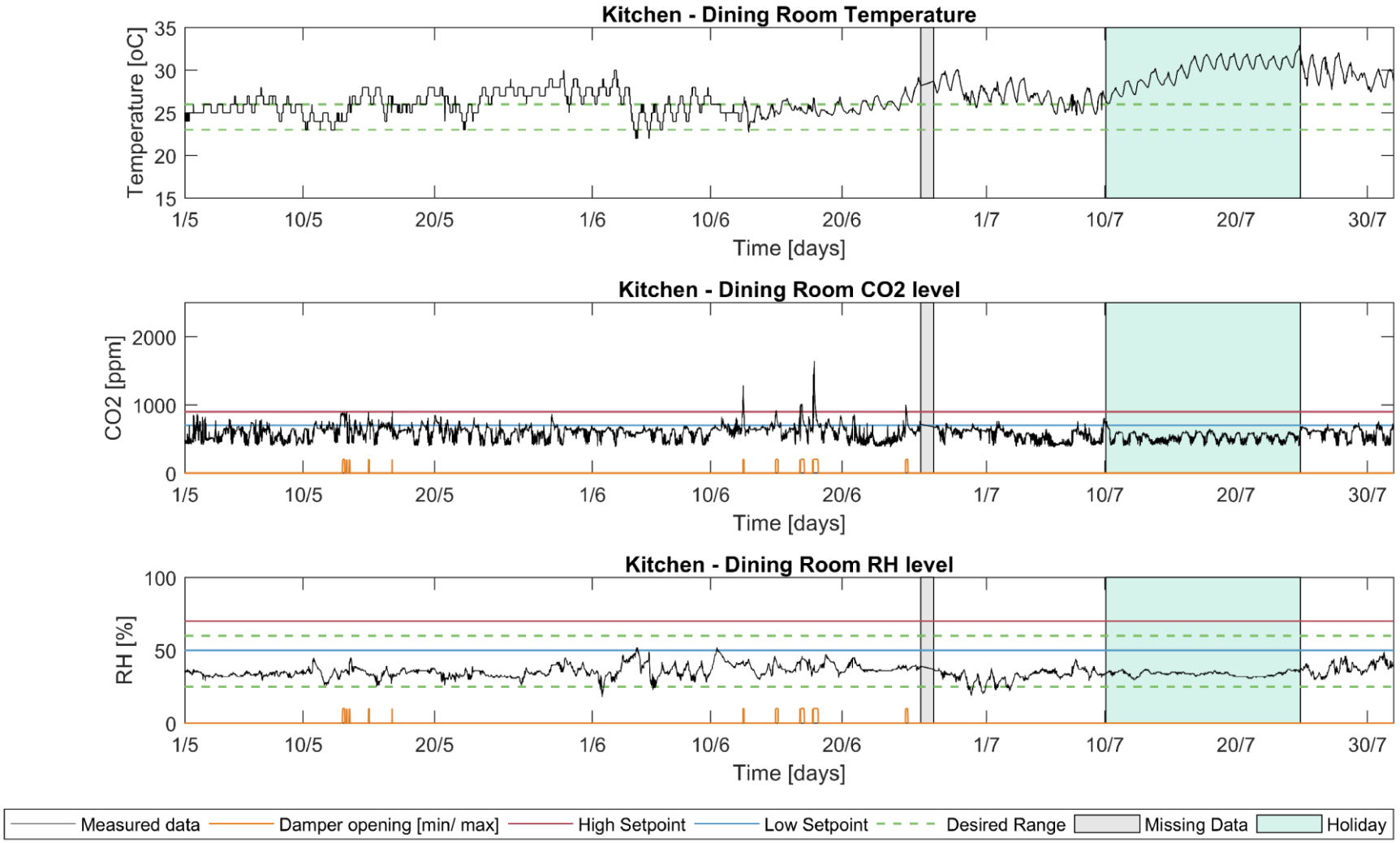

Figure 33: Graphs for temperature, CO_2 level and relative humidity during the 3 months period (May, June, July) – Kitchen/ Dining Room

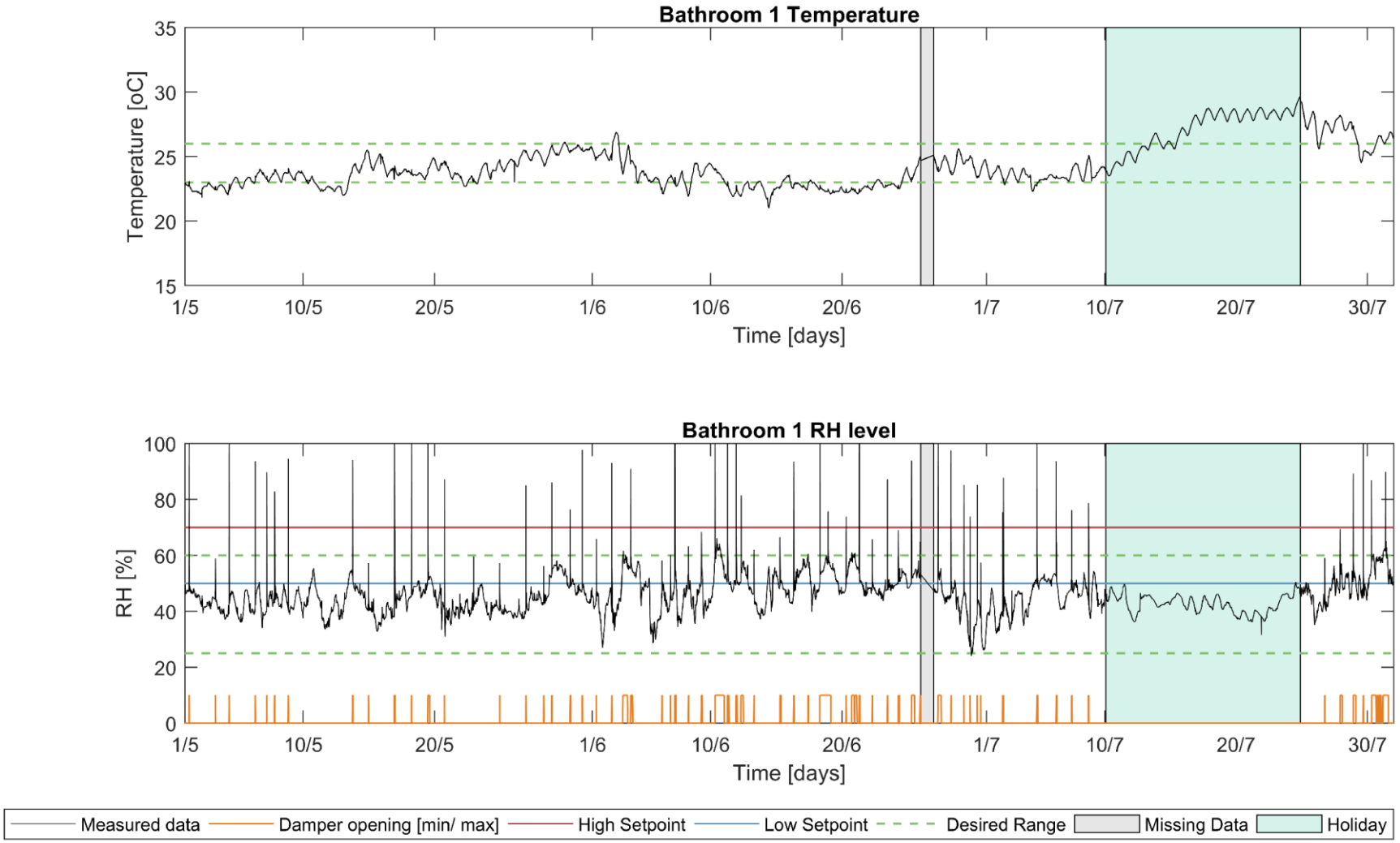

Figure 34: Graphs for temperature, CO_2 level and relative humidity during the 3 months period (May, June, July) – Bathroom 1

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